FIG.1

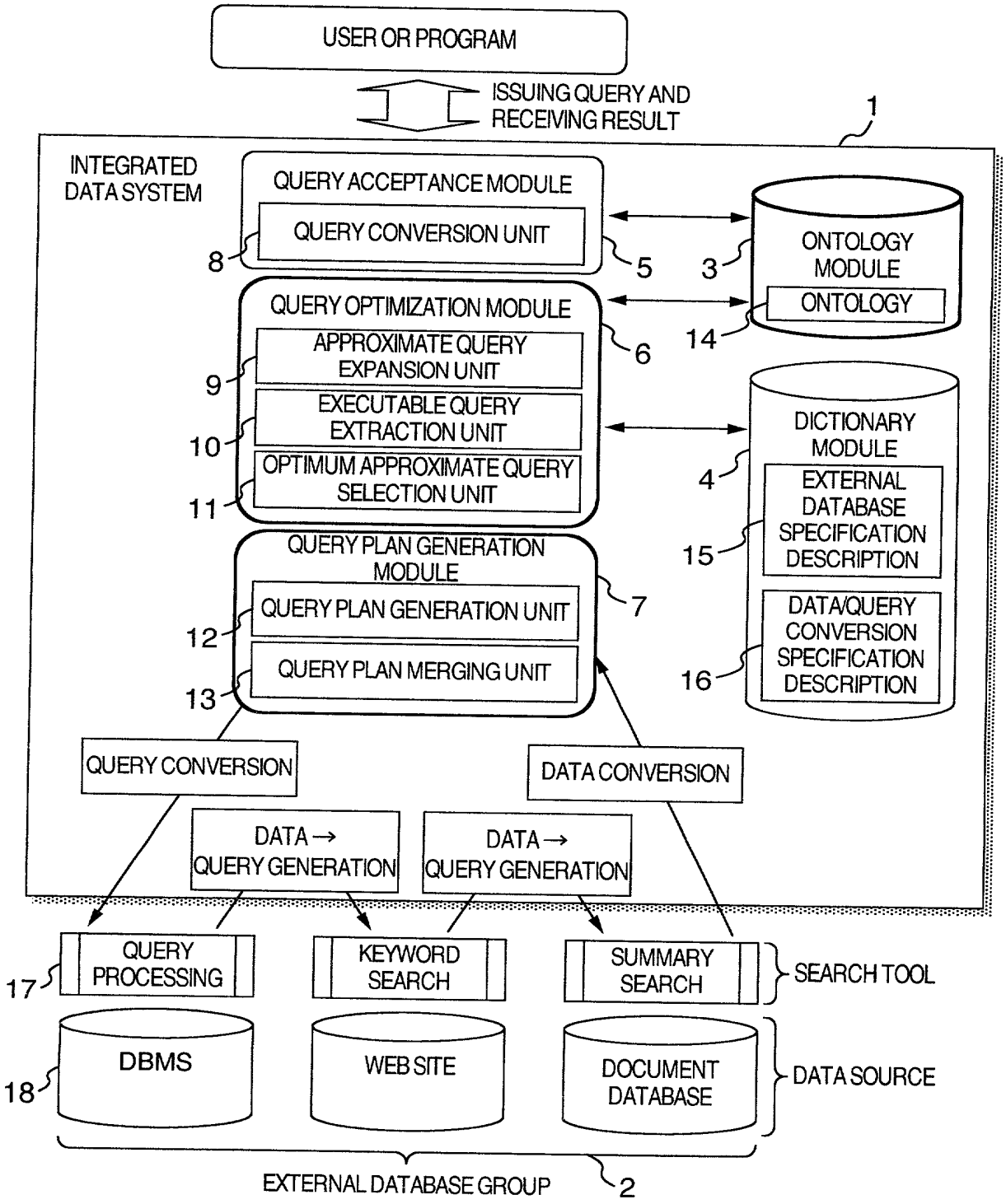

USER OR PROGRAM
ISSUING QUERY AND RECEIVING RESULT
1
INTEGRATED DATA SYSTEM
QUERY ACCEPTANCE MODULE
QUERY CONVERSION UNIT
8
5
3
ONTOLOGY MODULE
ONTOLOGY
14
QUERY OPTIMIZATION MODULE
6
APPROXIMATE QUERY EXPANSION UNIT
9
EXECUTABLE QUERY EXTRACTION UNIT
10
OPTIMUM APPROXIMATE QUERY SELECTION UNIT
11
DICTIONARY MODULE
4
EXTERNAL DATABASE SPECIFICATION DESCRIPTION
15
DATA/QUERY CONVERSION SPECIFICATION DESCRIPTION
16
QUERY PLAN GENERATION MODULE
7
QUERY PLAN GENERATION UNIT
12
QUERY PLAN MERGING UNIT
13
QUERY CONVERSION
DATA CONVERSION
DATA → QUERY GENERATION
DATA → QUERY GENERATION
QUERY PROCESSING
17
KEYWORD SEARCH
SUMMARY SEARCH
SEARCH TOOL
DBMS
18
WEB SITE
DOCUMENT DATABASE
DATA SOURCE
EXTERNAL DATABASE GROUP
2

FIG.2

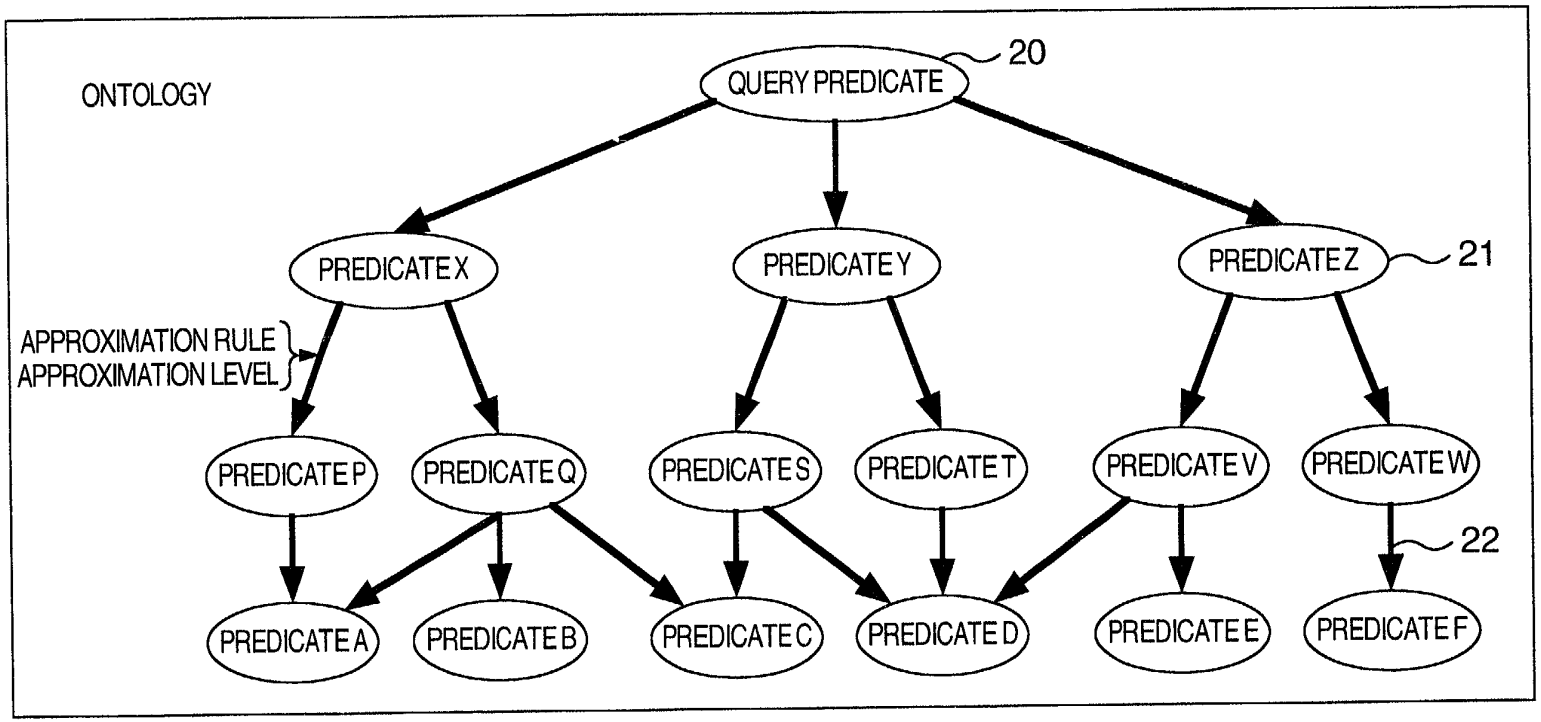

ONTOLOGY
QUERY PREDICATE
20
PREDICATE X
PREDICATE Y
PREDICATE Z
21
APPROXIMATION RULE
APPROXIMATION LEVEL
PREDICATE P
PREDICATE Q
PREDICATE S
PREDICATE T
PREDICATE V
PREDICATE W
22
PREDICATE A
PREDICATE B
PREDICATE C
PREDICATE D
PREDICATE E
PREDICATE F

FIG.3

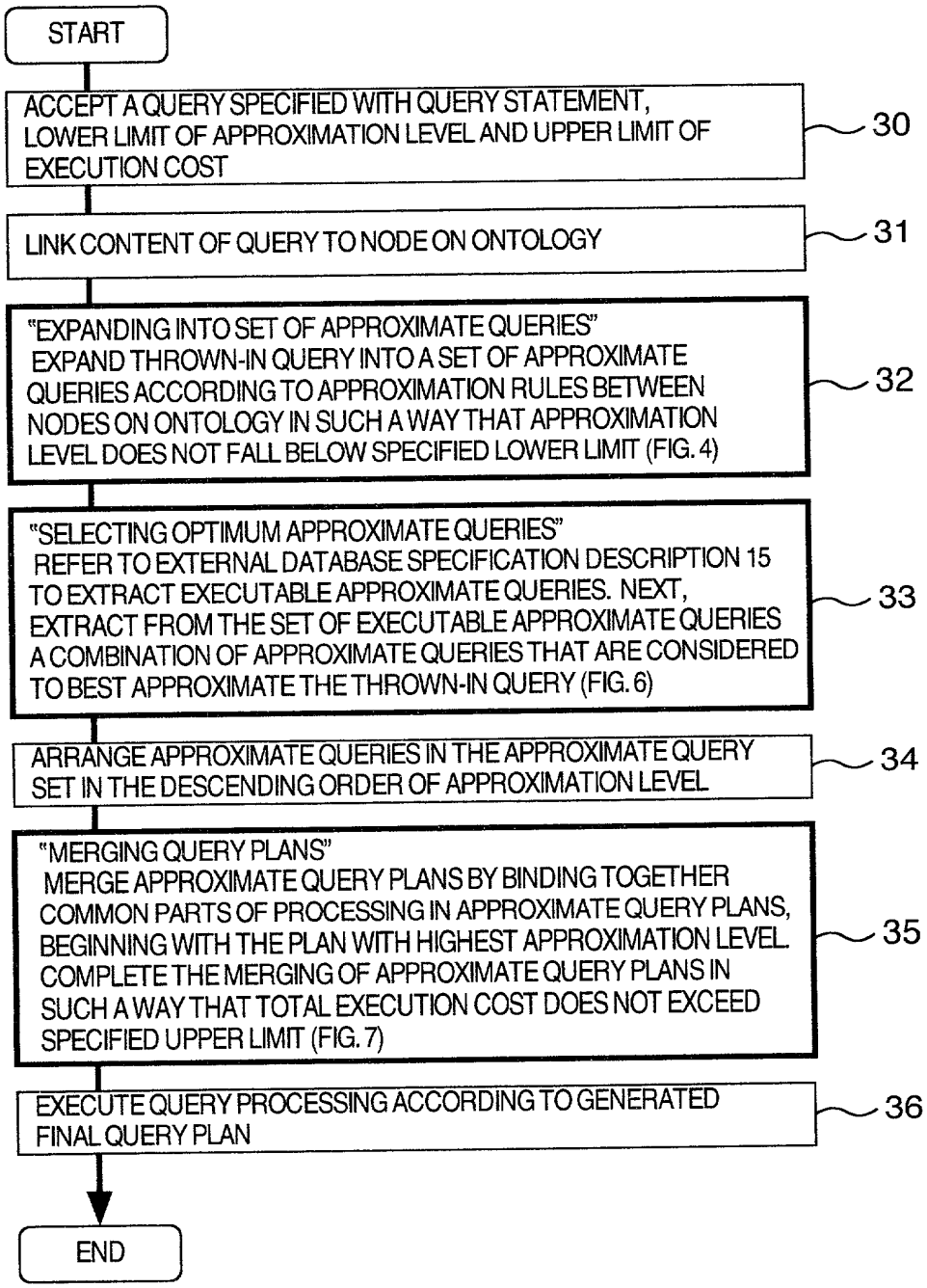

START
ACCEPT A QUERY SPECIFIED WITH QUERY STATEMENT, LOWER LIMIT OF APPROXIMATION LEVEL AND UPPER LIMIT OF EXECUTION COST
30
LINK CONTENT OF QUERY TO NODE ON ONTOLOGY
31
"EXPANDING INTO SET OF APPROXIMATE QUERIES" EXPAND THROWN-IN QUERY INTO A SET OF APPROXIMATE QUERIES ACCORDING TO APPROXIMATION RULES BETWEEN NODES ON ONTOLOGY IN SUCH A WAY THAT APPROXIMATION LEVEL DOES NOT FALL BELOW SPECIFIED LOWER LIMIT (FIG. 4)
32
"SELECTING OPTIMUM APPROXIMATE QUERIES" REFER TO EXTERNAL DATABASE SPECIFICATION DESCRIPTION 15 TO EXTRACT EXECUTABLE APPROXIMATE QUERIES. NEXT, EXTRACT FROM THE SET OF EXECUTABLE APPROXIMATE QUERIES A COMBINATION OF APPROXIMATE QUERIES THAT ARE CONSIDERED TO BEST APPROXIMATE THE THROWN-IN QUERY (FIG. 6)
33
ARRANGE APPROXIMATE QUERIES IN THE APPROXIMATE QUERY SET IN THE DESCENDING ORDER OF APPROXIMATION LEVEL
34
"MERGING QUERY PLANS" MERGE APPROXIMATE QUERY PLANS BY BINDING TOGETHER COMMON PARTS OF PROCESSING IN APPROXIMATE QUERY PLANS, BEGINNING WITH THE PLAN WITH HIGHEST APPROXIMATION LEVEL. COMPLETE THE MERGING OF APPROXIMATE QUERY PLANS IN SUCH A WAY THAT TOTAL EXECUTION COST DOES NOT EXCEED SPECIFIED UPPER LIMIT (FIG. 7)
35
EXECUTE QUERY PROCESSING ACCORDING TO GENERATED FINAL QUERY PLAN
36
END

FIG.4

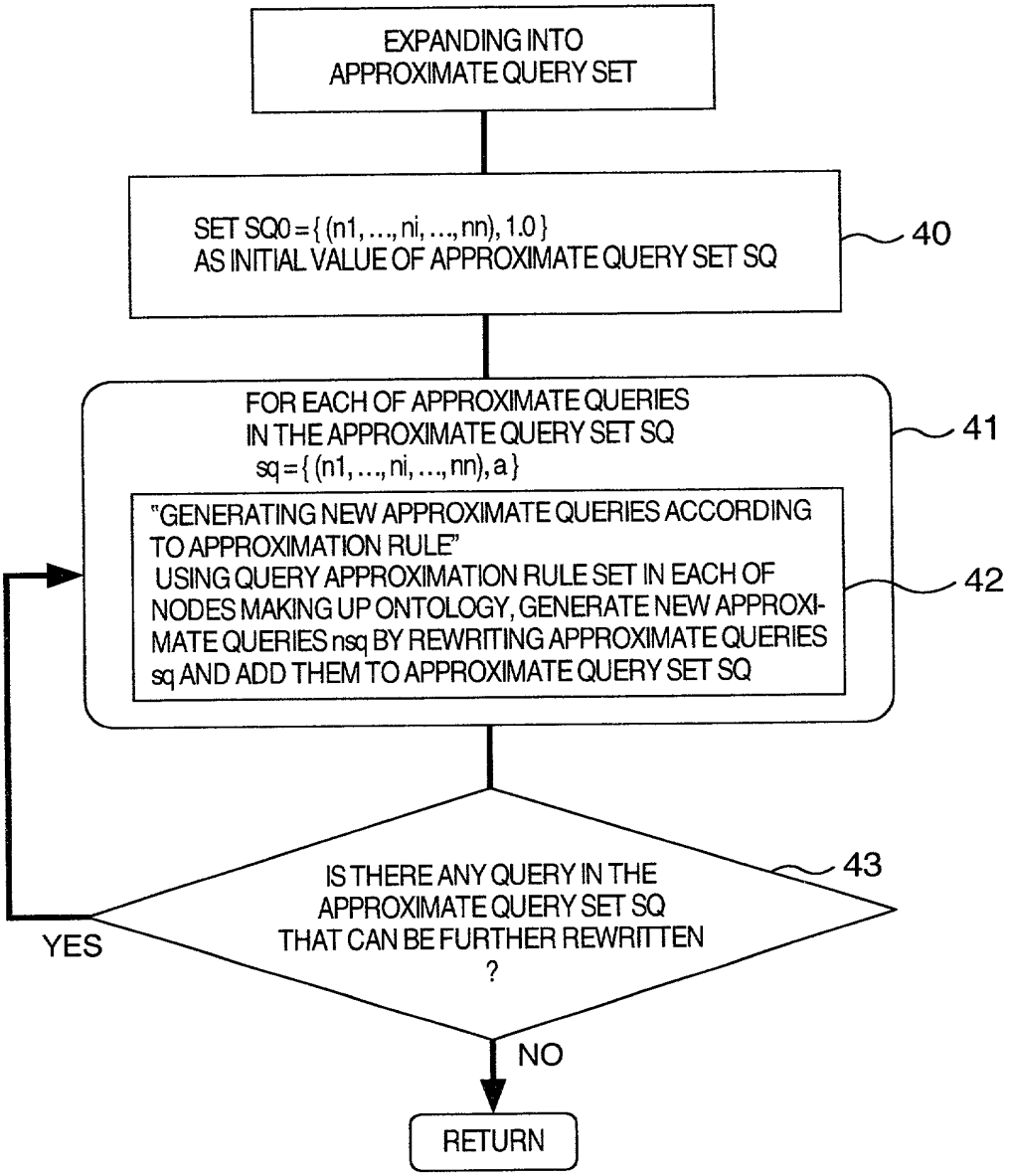

EXPANDING INTO APPROXIMATE QUERY SET
SET SQ0 = { (n1, ..., ni, ..., nn), 1.0 } AS INITIAL VALUE OF APPROXIMATE QUERY SET SQ
40
FOR EACH OF APPROXIMATE QUERIES IN THE APPROXIMATE QUERY SET SQ
sq = { (n1, ..., ni, ..., nn), a }
41
"GENERATING NEW APPROXIMATE QUERIES ACCORDING TO APPROXIMATION RULE"
USING QUERY APPROXIMATION RULE SET IN EACH OF NODES MAKING UP ONTOLOGY, GENERATE NEW APPROXIMATE QUERIES nsq BY REWRITING APPROXIMATE QUERIES sq AND ADD THEM TO APPROXIMATE QUERY SET SQ
42
IS THERE ANY QUERY IN THE APPROXIMATE QUERY SET SQ THAT CAN BE FURTHER REWRITTEN ?
43
YES
NO
RETURN

FIG.5

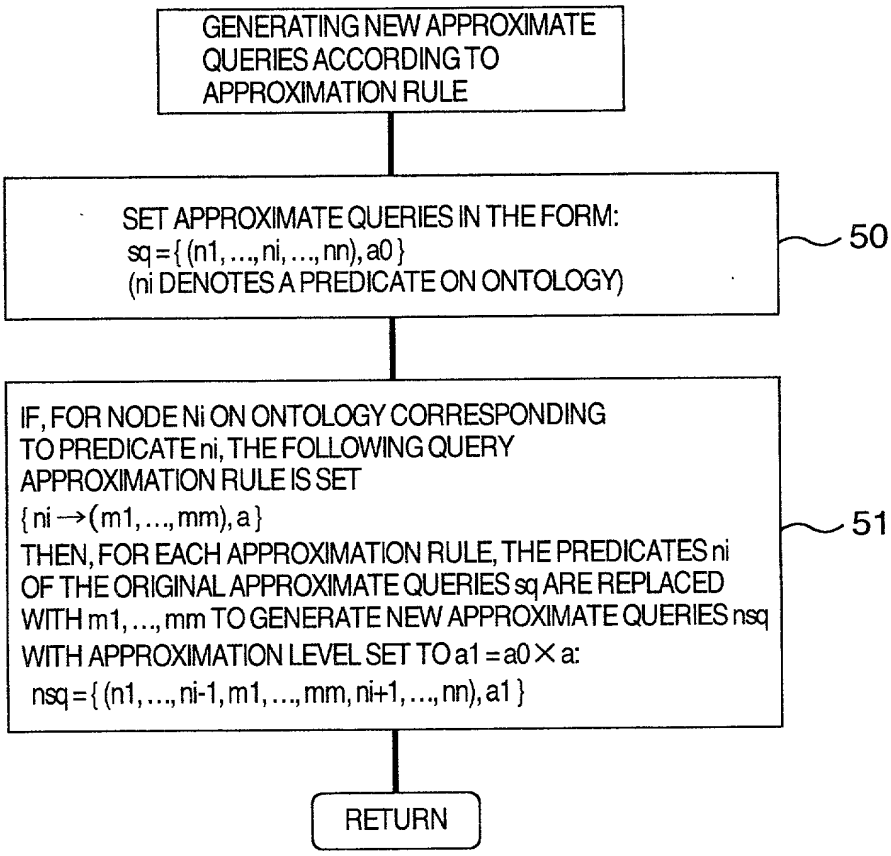

GENERATING NEW APPROXIMATE QUERIES ACCORDING TO APPROXIMATION RULE
SET APPROXIMATE QUERIES IN THE FORM:
sq={(n1,...,ni,...,nn),a0}
(ni DENOTES A PREDICATE ON ONTOLOGY)
50
IF, FOR NODE Ni ON ONTOLOGY CORRESPONDING TO PREDICATE ni, THE FOLLOWING QUERY APPROXIMATION RULE IS SET
{ni→(m1,...,mm),a}
THEN, FOR EACH APPROXIMATION RULE, THE PREDICATES ni OF THE ORIGINAL APPROXIMATE QUERIES sq ARE REPLACED WITH m1,...,mm TO GENERATE NEW APPROXIMATE QUERIES nsq WITH APPROXIMATION LEVEL SET TO a1=a0×a:
nsq={(n1,...,ni-1,m1,...,mm,ni+1,...,nn),a1}
51
RETURN

FIG.6

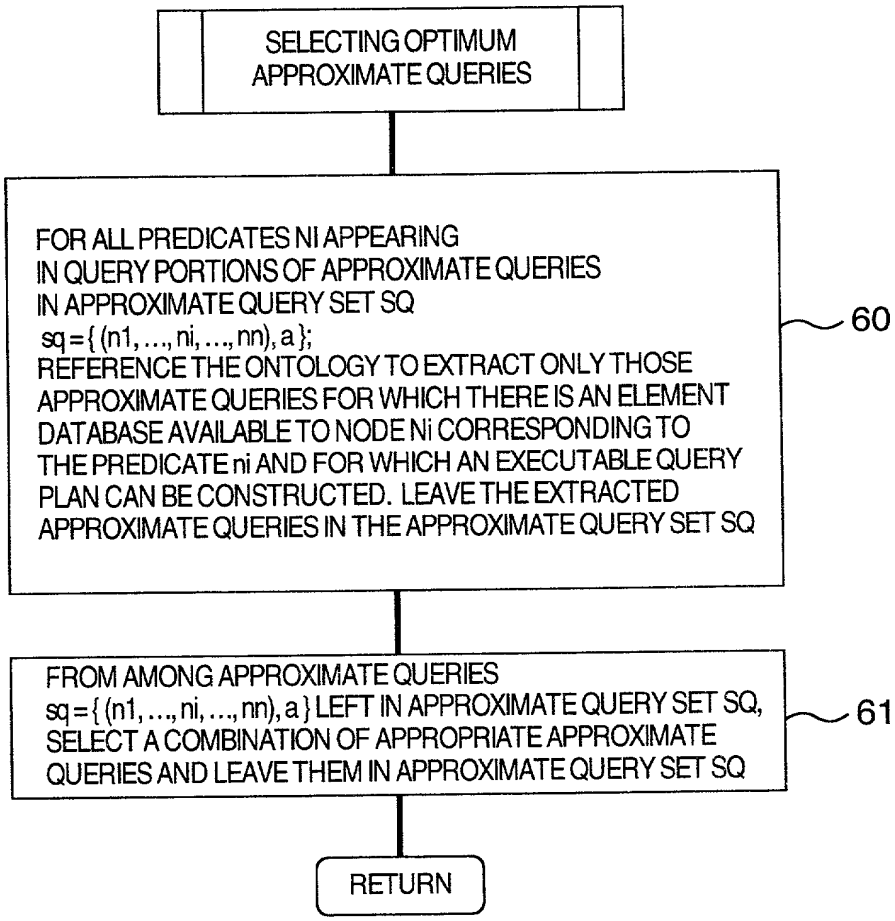

SELECTING OPTIMUM APPROXIMATE QUERIES
FOR ALL PREDICATES NI APPEARING IN QUERY PORTIONS OF APPROXIMATE QUERIES IN APPROXIMATE QUERY SET SQ
sq={(n1,...,ni,...,nn),a};
REFERENCE THE ONTOLOGY TO EXTRACT ONLY THOSE APPROXIMATE QUERIES FOR WHICH THERE IS AN ELEMENT DATABASE AVAILABLE TO NODE Ni CORRESPONDING TO THE PREDICATE ni AND FOR WHICH AN EXECUTABLE QUERY PLAN CAN BE CONSTRUCTED. LEAVE THE EXTRACTED APPROXIMATE QUERIES IN THE APPROXIMATE QUERY SET SQ
60
FROM AMONG APPROXIMATE QUERIES sq={(n1,...,ni,...,nn),a} LEFT IN APPROXIMATE QUERY SET SQ, SELECT A COMBINATION OF APPROPRIATE APPROXIMATE QUERIES AND LEAVE THEM IN APPROXIMATE QUERY SET SQ
61
RETURN

FIG.7

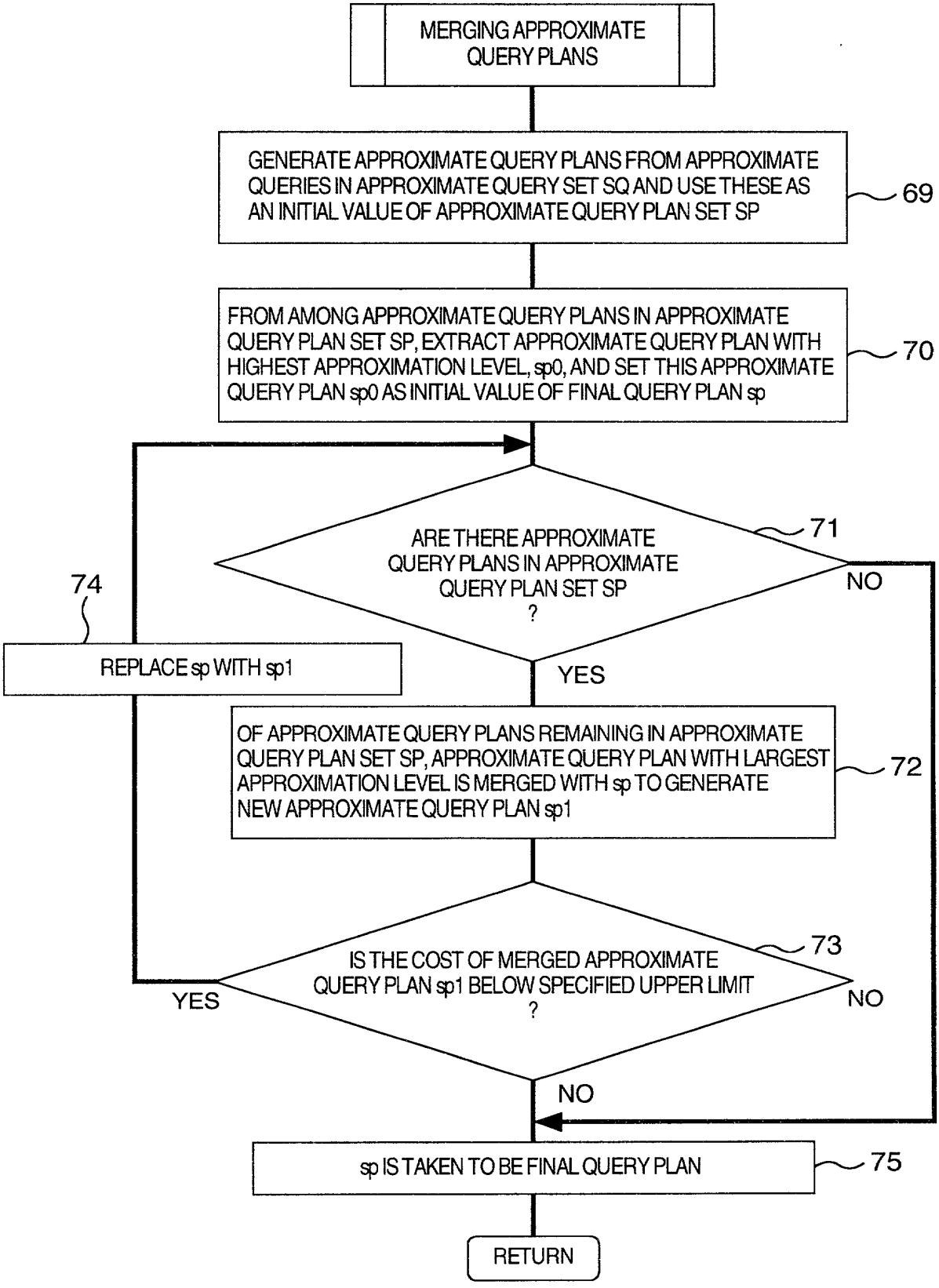
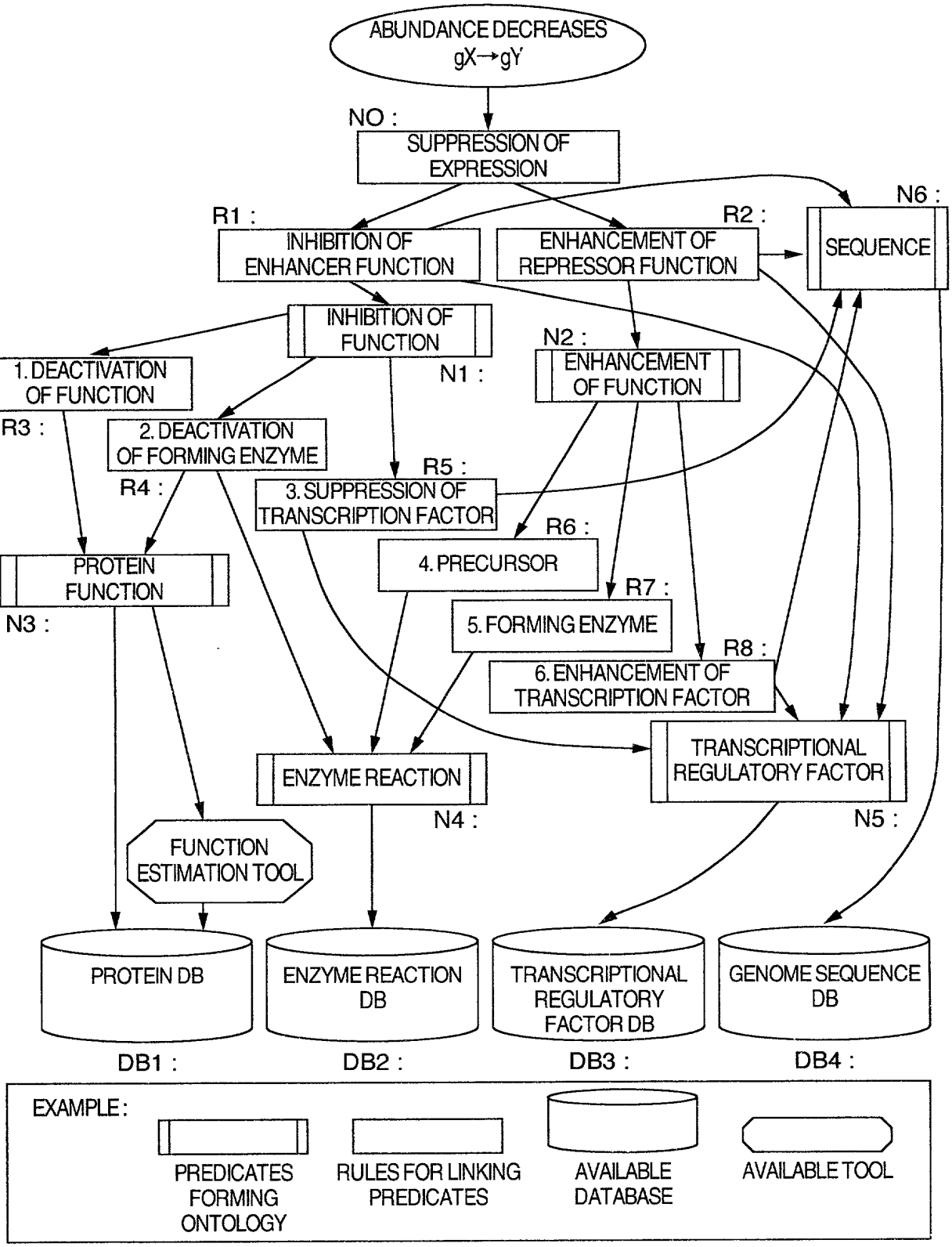

MERGING APPROXIMATE QUERY PLANS
GENERATE APPROXIMATE QUERY PLANS FROM APPROXIMATE QUERIES IN APPROXIMATE QUERY SET SQ AND USE THESE AS AN INITIAL VALUE OF APPROXIMATE QUERY PLAN SET SP
69
FROM AMONG APPROXIMATE QUERY PLANS IN APPROXIMATE QUERY PLAN SET SP, EXTRACT APPROXIMATE QUERY PLAN WITH HIGHEST APPROXIMATION LEVEL, sp0, AND SET THIS APPROXIMATE QUERY PLAN sp0 AS INITIAL VALUE OF FINAL QUERY PLAN sp
70
ARE THERE APPROXIMATE QUERY PLANS IN APPROXIMATE QUERY PLAN SET SP ?
71
NO
YES
74
REPLACE sp WITH sp1
OF APPROXIMATE QUERY PLANS REMAINING IN APPROXIMATE QUERY PLAN SET SP, APPROXIMATE QUERY PLAN WITH LARGEST APPROXIMATION LEVEL IS MERGED WITH sp TO GENERATE NEW APPROXIMATE QUERY PLAN sp1
72
IS THE COST OF MERGED APPROXIMATE QUERY PLAN sp1 BELOW SPECIFIED UPPER LIMIT ?
73
YES
NO
NO
sp IS TAKEN TO BE FINAL QUERY PLAN
75
RETURN

FIG.8


ABUNDANCE DECREASES
gX→gY
NO :
SUPPRESSION OF EXPRESSION
R1 :
INHIBITION OF ENHANCER FUNCTION
R2 :
ENHANCEMENT OF REPRESSOR FUNCTION
N6 :
SEQUENCE
INHIBITION OF FUNCTION
N1 :
N2 :
ENHANCEMENT OF FUNCTION
1. DEACTIVATION OF FUNCTION
R3 :
2. DEACTIVATION OF FORMING ENZYME
R4 :
R5 :
3. SUPPRESSION OF TRANSCRIPTION FACTOR
R6 :
4. PRECURSOR
R7 :
5. FORMING ENZYME
R8 :
6. ENHANCEMENT OF TRANSCRIPTION FACTOR
PROTEIN FUNCTION
N3 :
ENZYME REACTION
N4 :
TRANSCRIPTIONAL REGULATORY FACTOR
N5 :
FUNCTION ESTIMATION TOOL
PROTEIN DB
ENZYME REACTION DB
TRANSCRIPTIONAL REGULATORY FACTOR DB
GENOME SEQUENCE DB
DB1 :
DB2 :
DB3 :
DB4 :
EXAMPLE :
PREDICATES FORMING ONTOLOGY
RULES FOR LINKING PREDICATES
AVAILABLE DATABASE
AVAILABLE TOOL

# FIG.9

SCHEMATIC DIAGRAM SHOWING A BIOMOLECULAR RELATION CORRESPONDING TO APPROXIMATION RULES

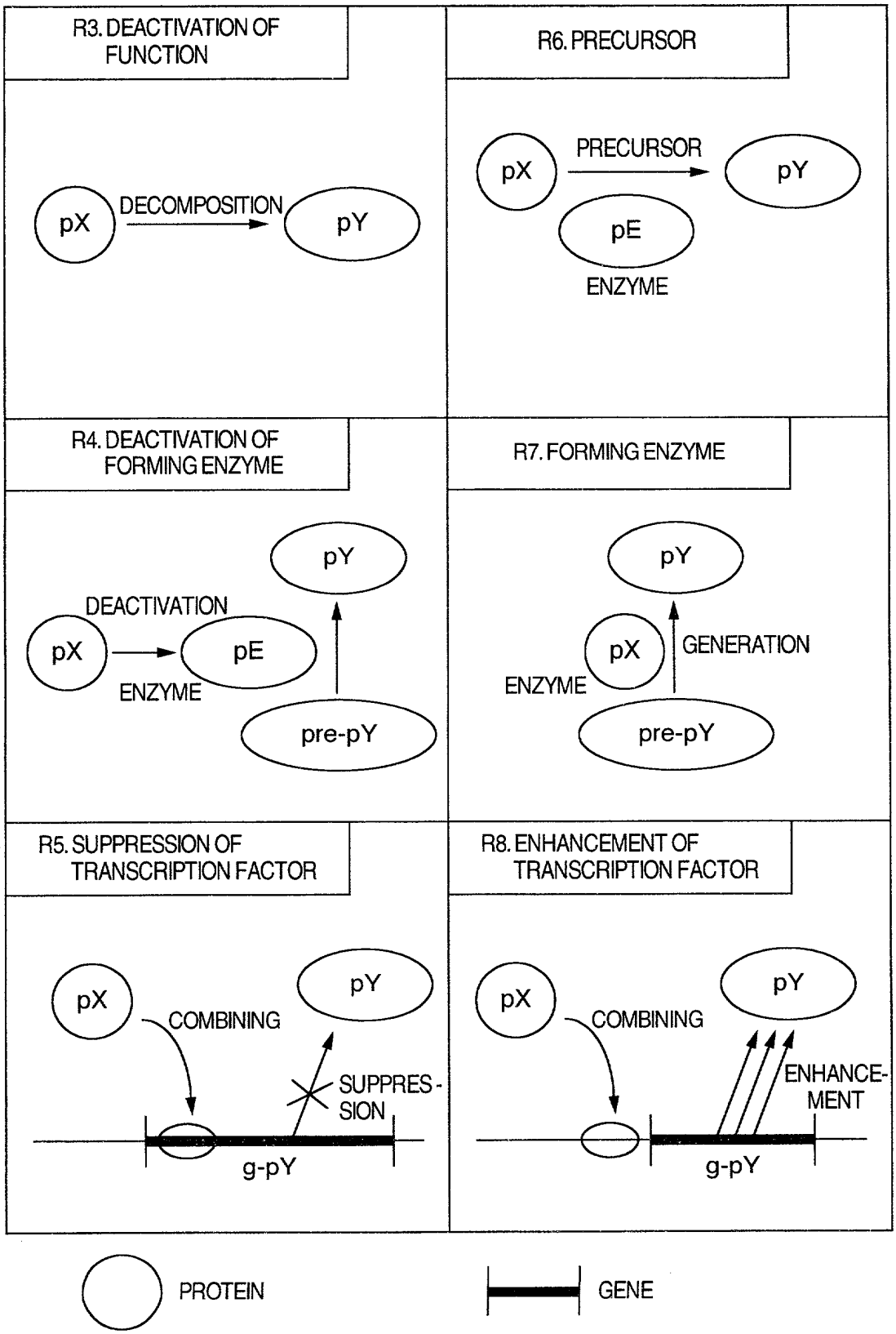


FIG.10

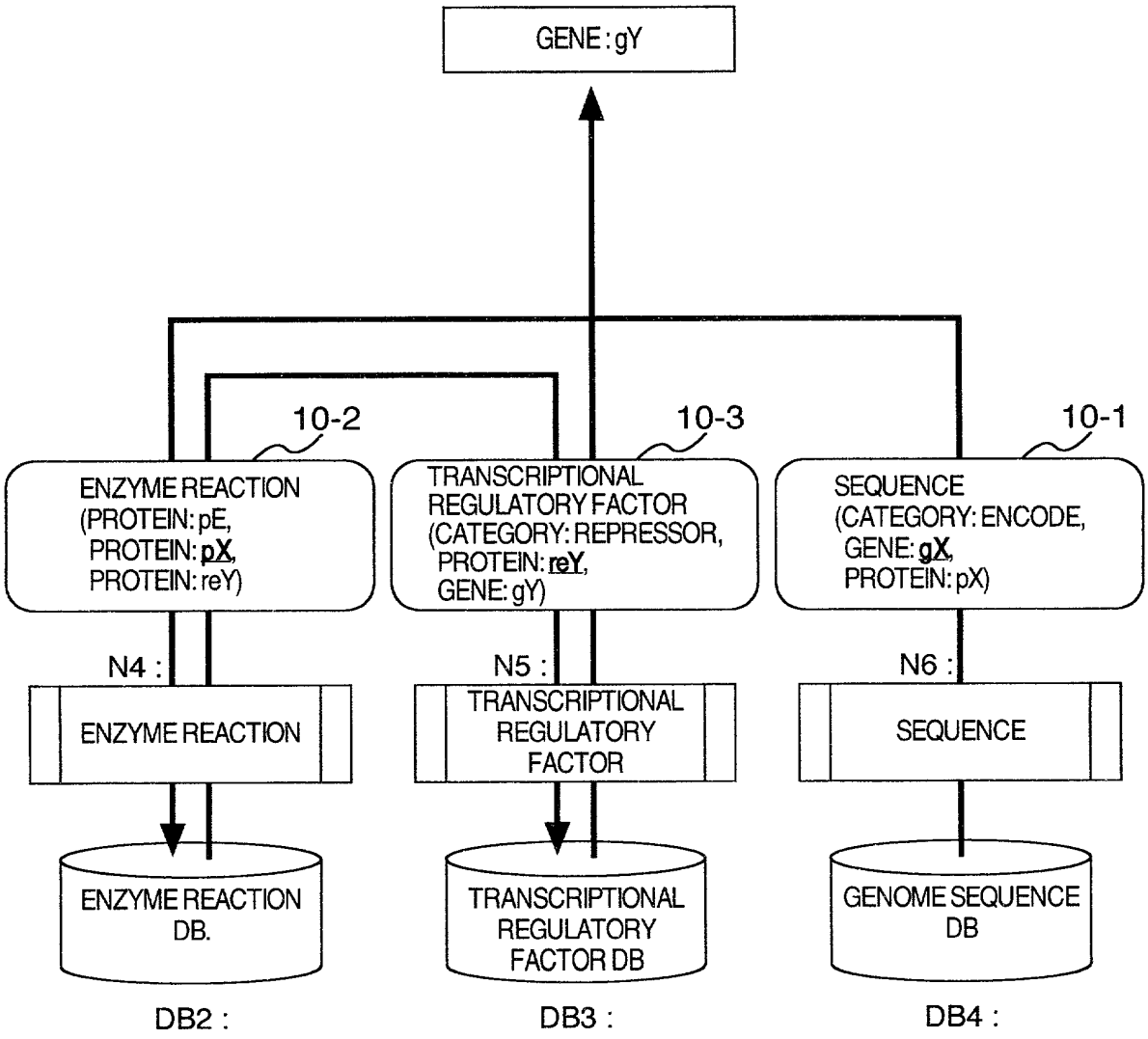
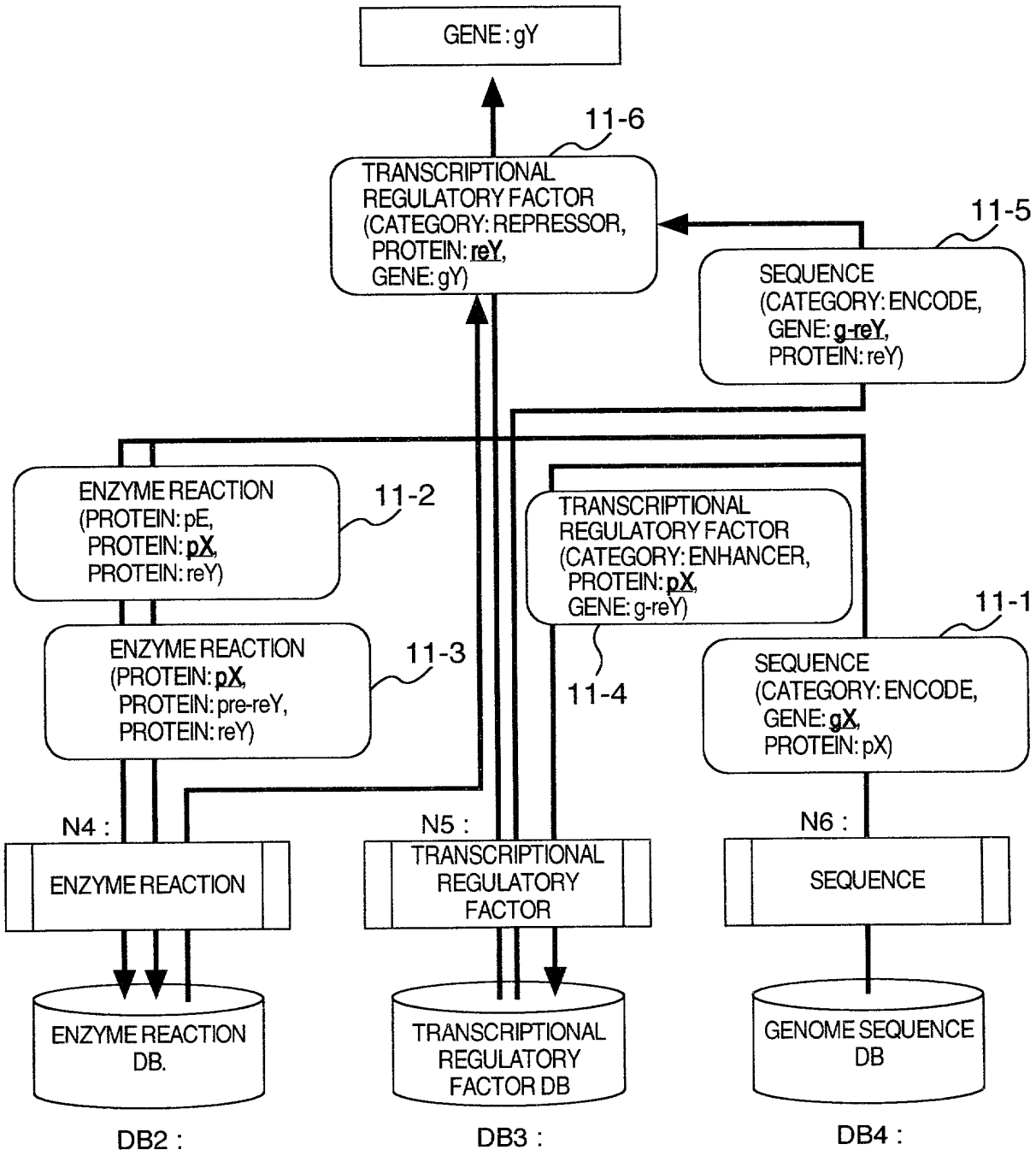

GENE : gY
10-2
10-3
10-1
ENZYME REACTION
(PROTEIN: pE,
PROTEIN: pX,
PROTEIN: reY)
TRANSCRIPTIONAL
REGULATORY FACTOR
(CATEGORY: REPRESSOR,
PROTEIN: reY,
GENE: gY)
SEQUENCE
(CATEGORY: ENCODE,
GENE: gX,
PROTEIN: pX)
N4 :
N5 :
N6 :
ENZYME REACTION
TRANSCRIPTIONAL
REGULATORY
FACTOR
SEQUENCE
ENZYME REACTION
DB.
TRANSCRIPTIONAL
REGULATORY
FACTOR DB
GENOME SEQUENCE
DB
DB2 :
DB3 :
DB4 :

FIG.11


GENE : gY
11-6
TRANSCRIPTIONAL REGULATORY FACTOR (CATEGORY: REPRESSOR, PROTEIN: reY, GENE: gY)
11-5
SEQUENCE (CATEGORY: ENCODE, GENE: g-reY, PROTEIN: reY)
ENZYME REACTION (PROTEIN: pE, PROTEIN: pX, PROTEIN: reY)
11-2
TRANSCRIPTIONAL REGULATORY FACTOR (CATEGORY: ENHANCER, PROTEIN: pX, GENE: g-reY)
11-1
ENZYME REACTION (PROTEIN: pX, PROTEIN: pre-reY, PROTEIN: reY)
11-3
11-4
SEQUENCE (CATEGORY: ENCODE, GENE: gX, PROTEIN: pX)
N4 :
N5 :
N6 :
ENZYME REACTION
TRANSCRIPTIONAL REGULATORY FACTOR
SEQUENCE
ENZYME REACTION DB.
TRANSCRIPTIONAL REGULATORY FACTOR DB
GENOME SEQUENCE DB
DB2 :
DB3 :
DB4 :